Overview of the LIFE Power Plant

Presentation

Georgia Tech Energy Speakers Series

November 16, 2011

Brian T. Debs

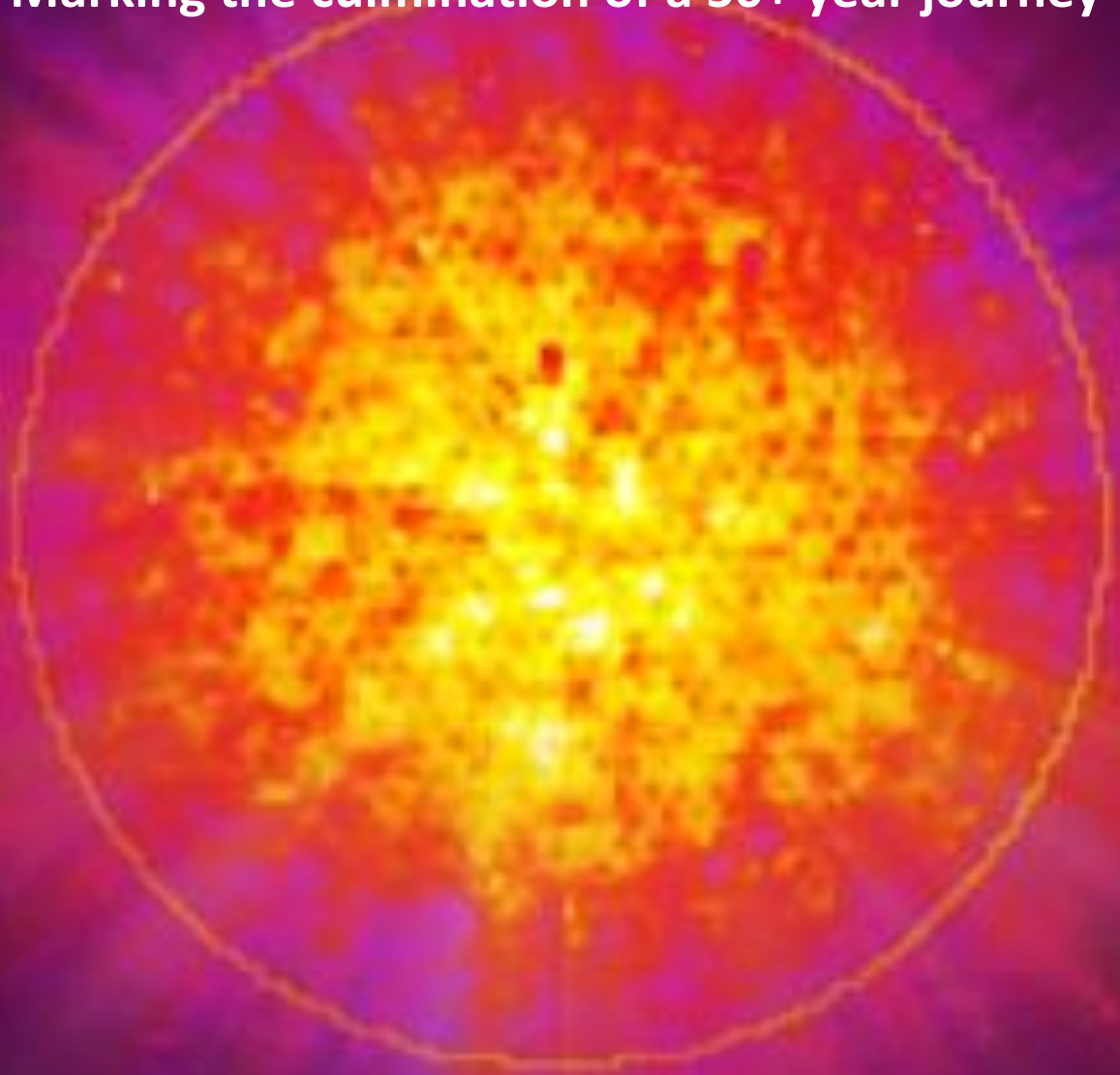
The Sun took about 50 million years to initiate fusion

How long will it take us here on Earth?

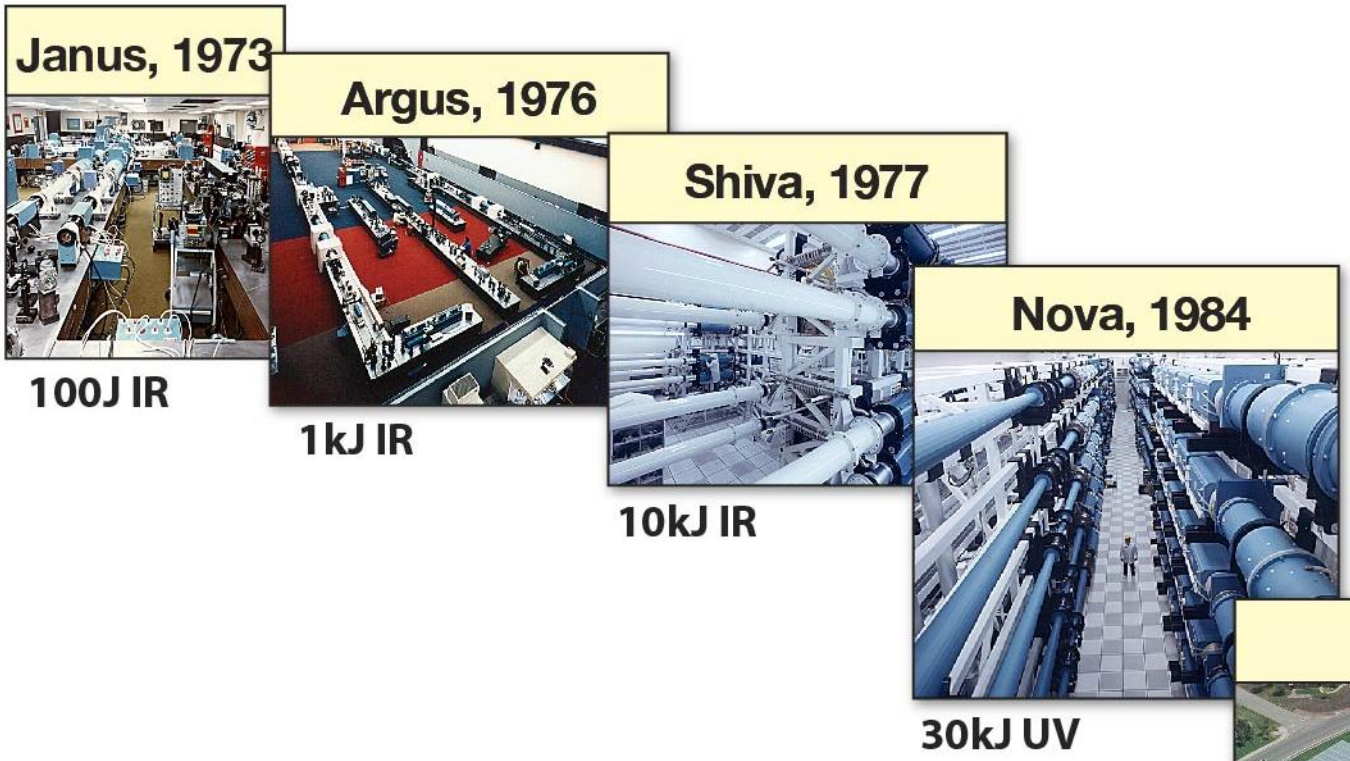

Ted Maiman
First laser
demonstrated on
May 16, 1960

John Nuckolls proposed to use lasers for fusion energy

Success with Ignition will herald a new era for fusion –
Marking the culmination of a 50+ year journey



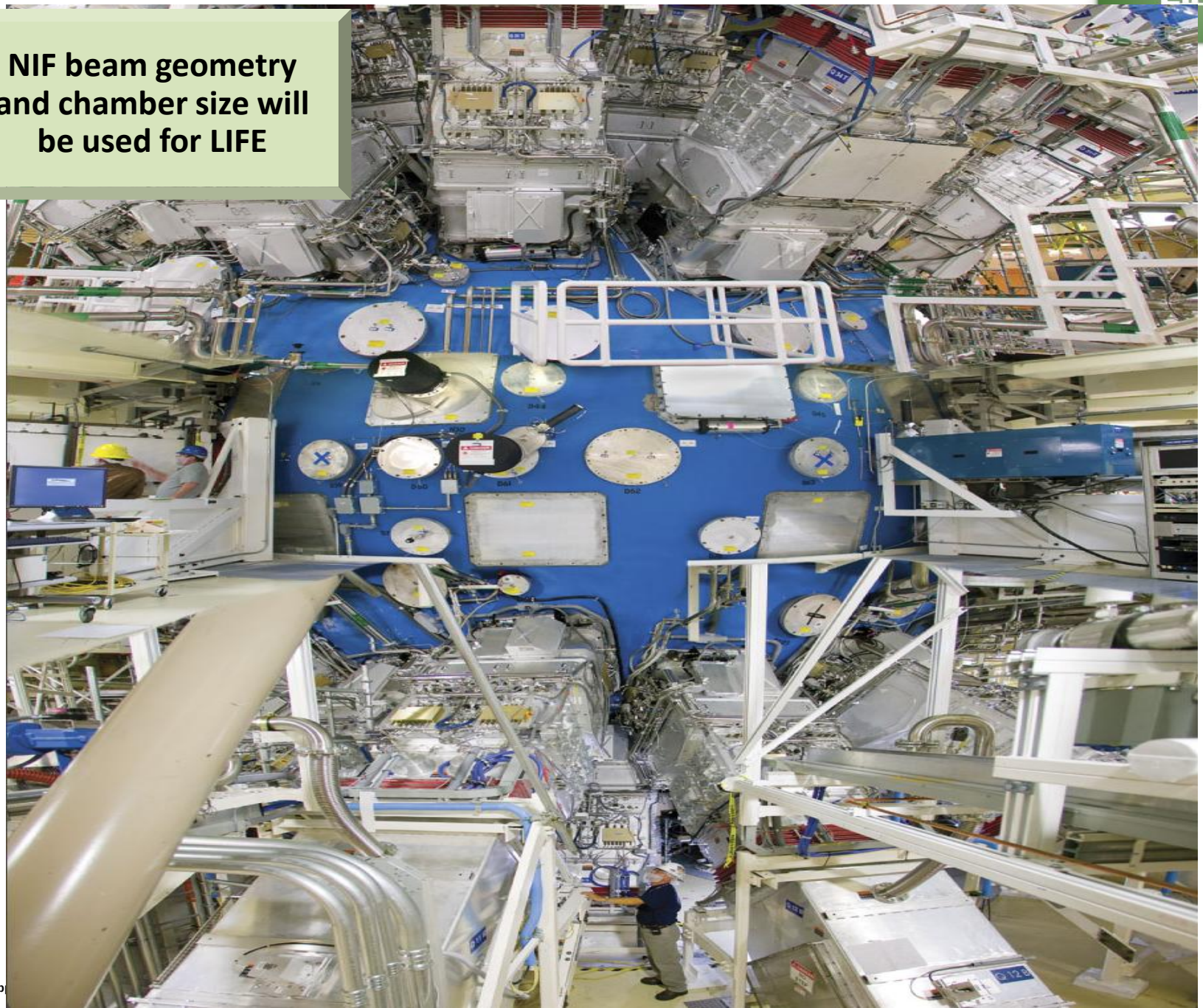
Laser Inertial Fusion Energy (LIFE) is the proof of concept

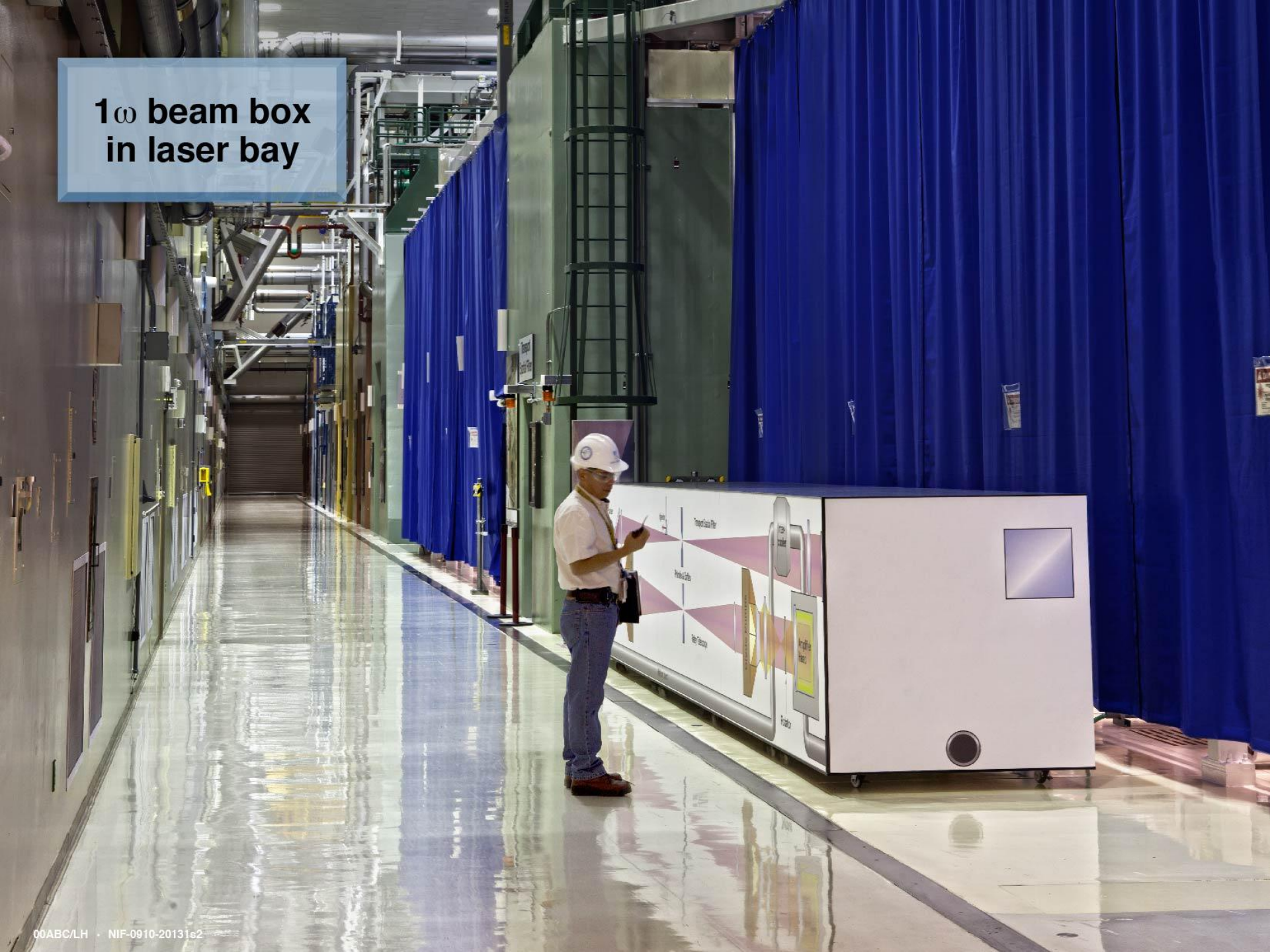


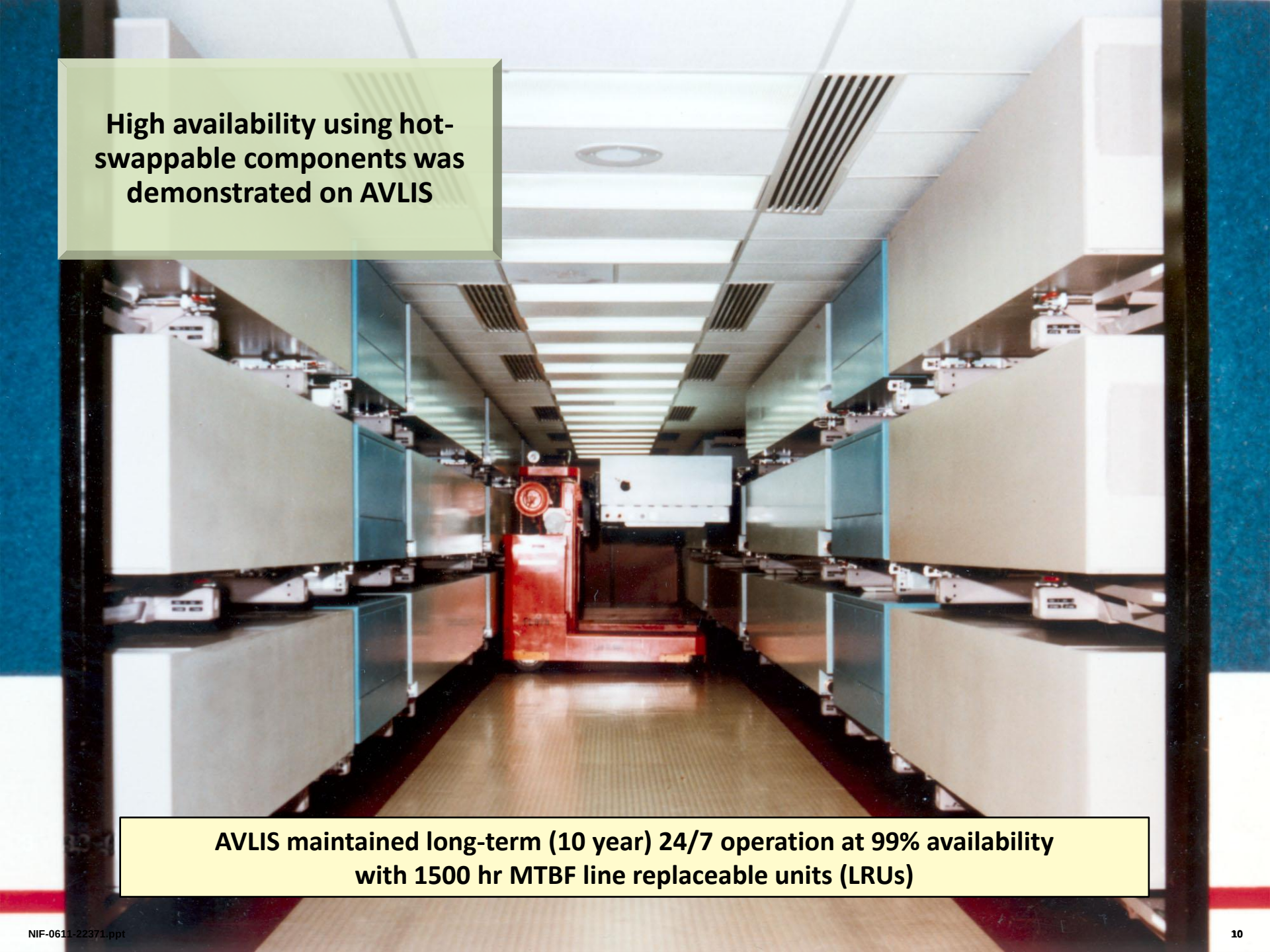
NIF will demonstrate full-scale performance


NIF is complete and
on the path to ignition
NIF

NIF beam geometry and chamber size will be used for LIFE




1ω beam box
in laser bay


High availability using hot-swappable components was demonstrated on AVLIS
AVLIS maintained long-term (10 year) 24/7 operation at 99% availability with 1500 hr MTBF line replaceable units (LRUs)

Laser Inertial Fusion Energy (LIFE) is our response to the Secretary's call for a post-ignition plan

"The National Ignition Facility is a marvel, and while the Laboratory will achieve ignition, we need to think about what we should be doing in a year or two from today.

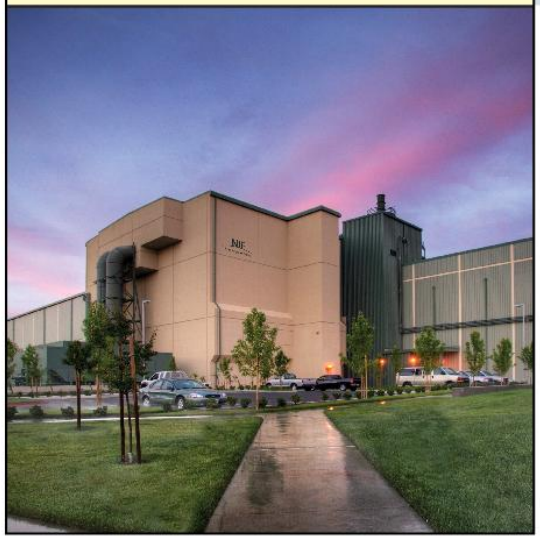
...DOE should assume ignition success in that planning, and not wait for NIF ignition to start such planning."

- Steven Chu U.S. Secretary of Energy

Energy Secretary Steven Chu

Fusion energy – soon enough to make a difference

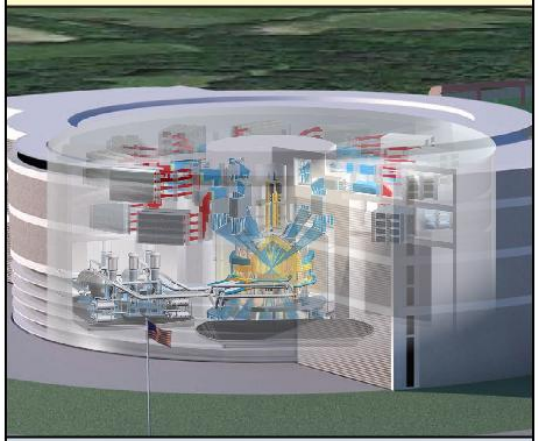
National Ignition Facility



2009 - Facility complete
2012 - Ignition

Performance

Market Entry Plants



1,000 MW_{th}

2020's

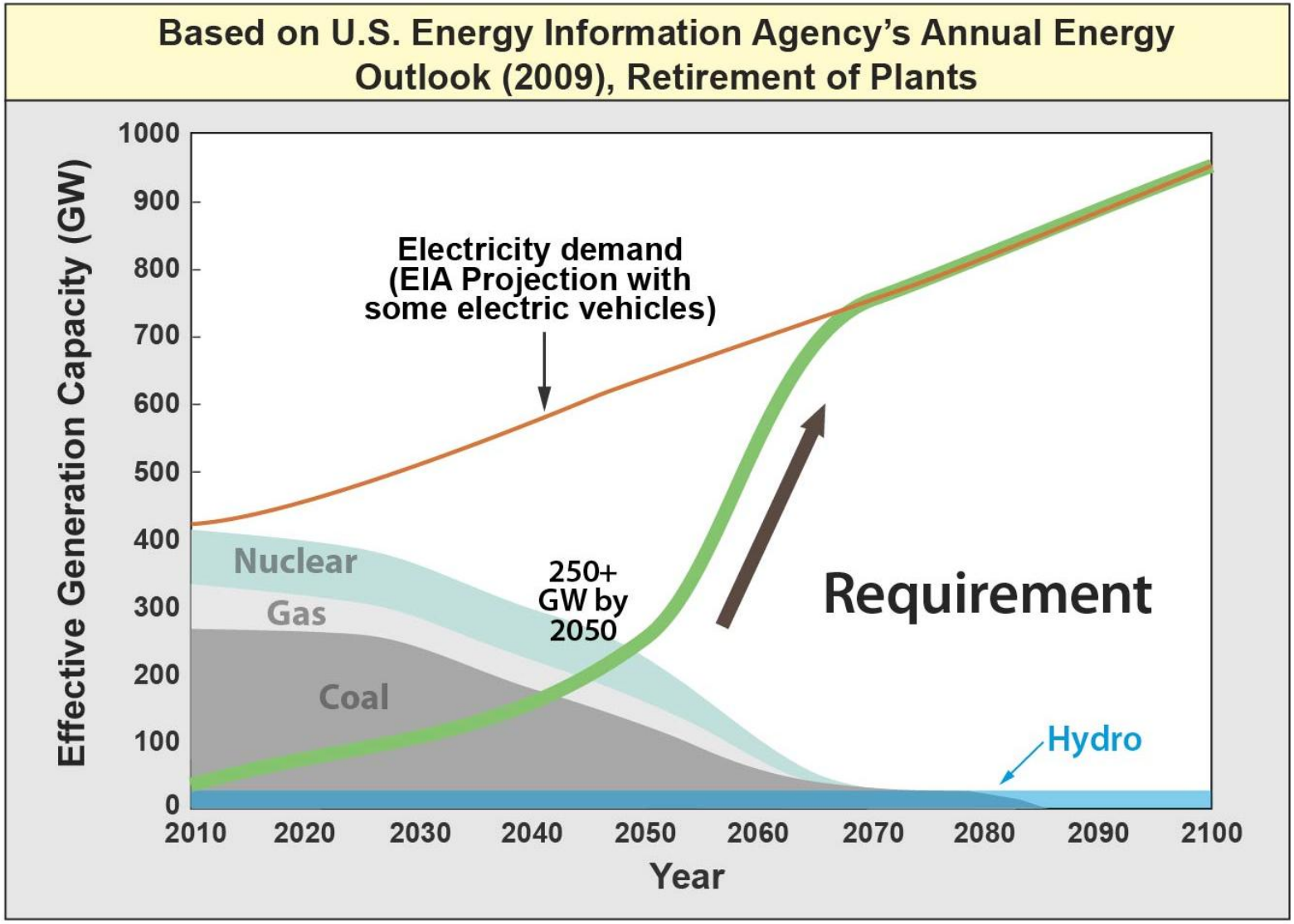
Integration

Mature LIFE Technology

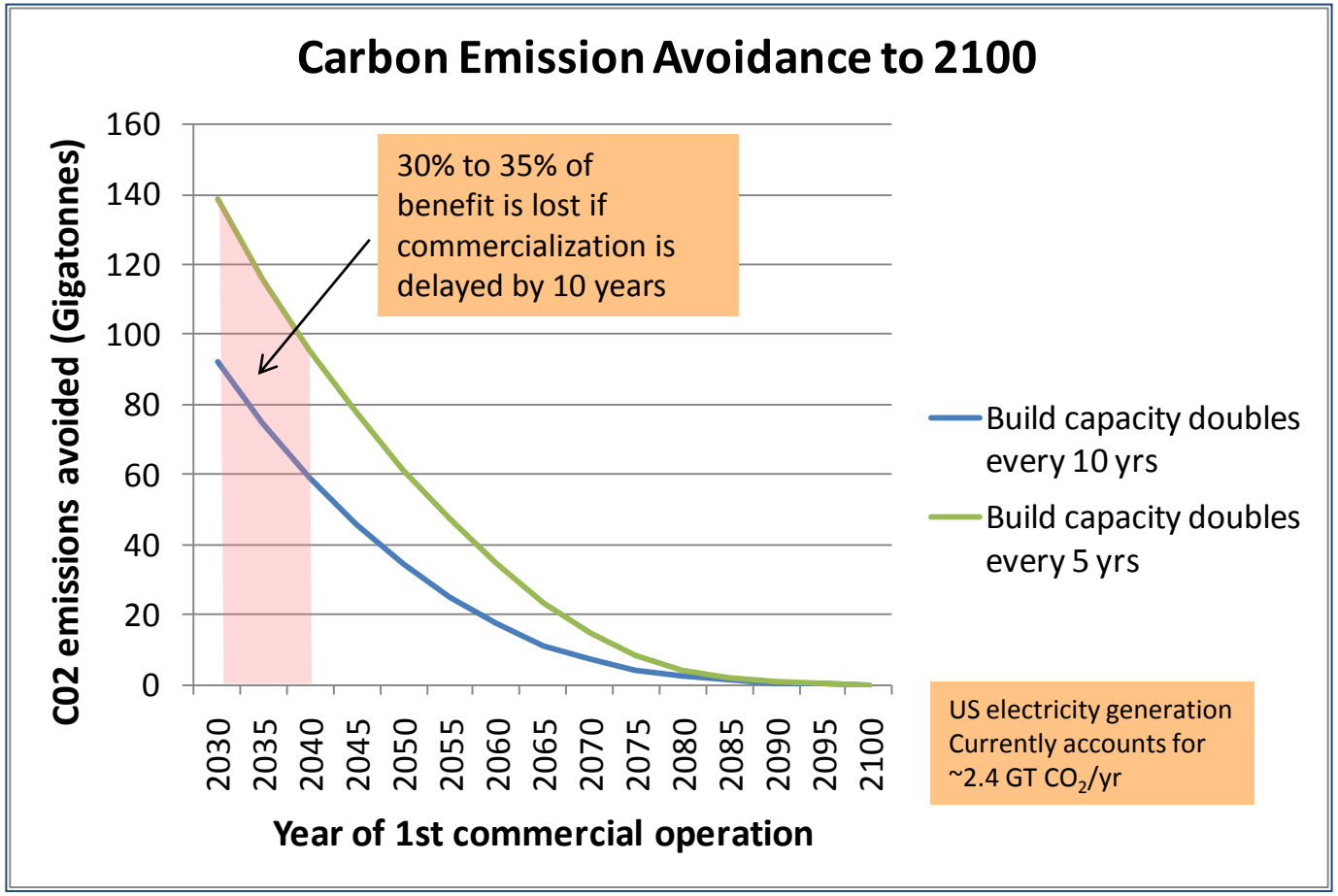
400 MW to 1,600 MW_e

2030's

If fusion is to be relevant, it needs to impact renewal of the US power plant fleet



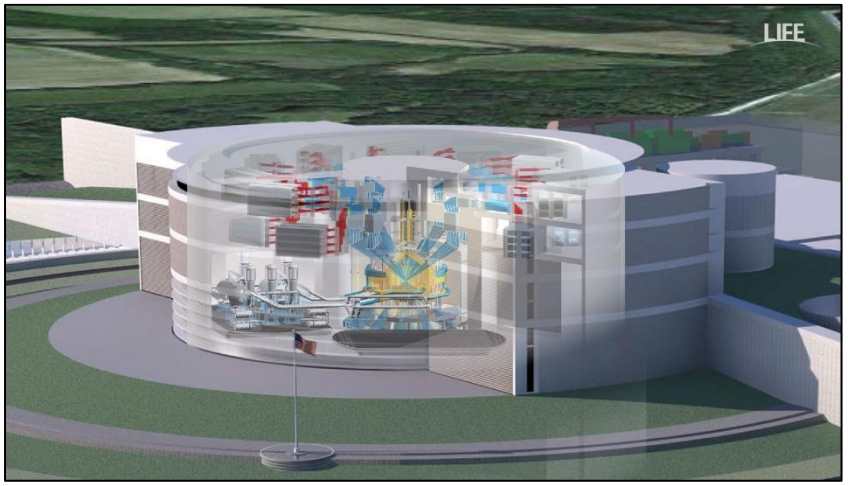
Carbon avoidance analysis illustrates need for early commercialization and rapid market penetration



*0.84kg CO_2 avoided/kWhr, assumes displacement of coal fired generation

Discussions with utilities and vendors have focused on end-user requirements for operations & licensing

Plant Primary Criteria (partial list)
Cost of electricity
Rate and cost of build
Licensing simplicity
Reliability, Availability, Maintainability, Inspectability (RAMI)
High capacity credit & load factor
Predictable shutdown & quick restart
Meet urban environmental and safety standards (minimize grid impact)
Public acceptability near load centers
Acceptable waste stream
Learn from commercial nuclear operating experience
O&M personnel qualifications
Timely delivery

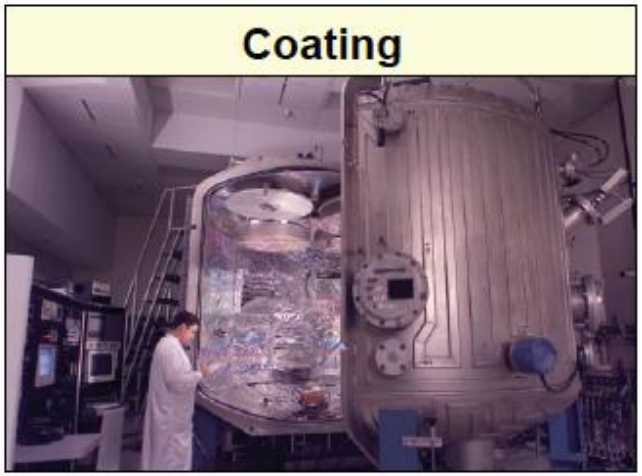


Use of commercially available materials and technologies

Focus on pure fusion, utility-scale, power-producing facility

Industrial partners were consulted to determine component availability, performance and cost

- **30+ major vendors engaged from the semiconductor, optics, laser, construction, controls, nuclear, project delivery and regulatory industries**
  - white papers produced detailing technology readiness and cost
- **Example output:**
  - **Semiconductor industry**: quantified laser diode performance, cost and capacity (joint paper from 14 companies)
  - **Optics industry**: glass production readiness (Schott APG-1)
  - **Manufacturing industry**: e.g. production of low activation HT-9 tubes
  - **Construction / Engineering** : facility design, commissioning and operations
  - Many of the key LIFE manufacturing processes are already in place

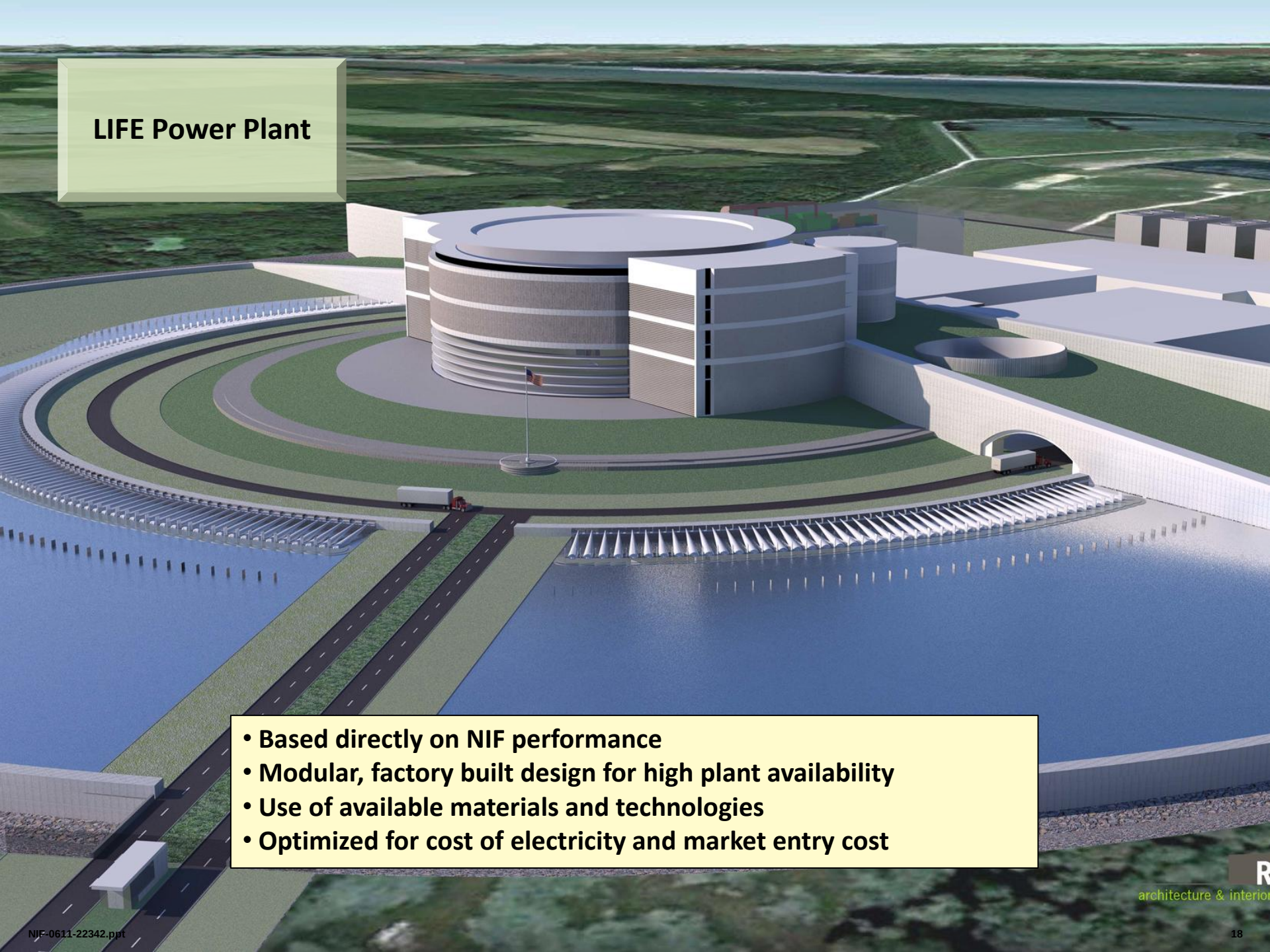


The LIFE power plant design presents attractive safety characteristics

- Primary source term disappears when system is off
- Runaway reaction is not possible
- Low residual decay heat: no need for active cooling
- Low and segregated tritium inventory
- In case of off-normal conditions the plant transitions passively to safe state
- Initial design basis accidents assessment shows no need for public evacuation
- No need for "safety class" structures, systems or components (SSCs)

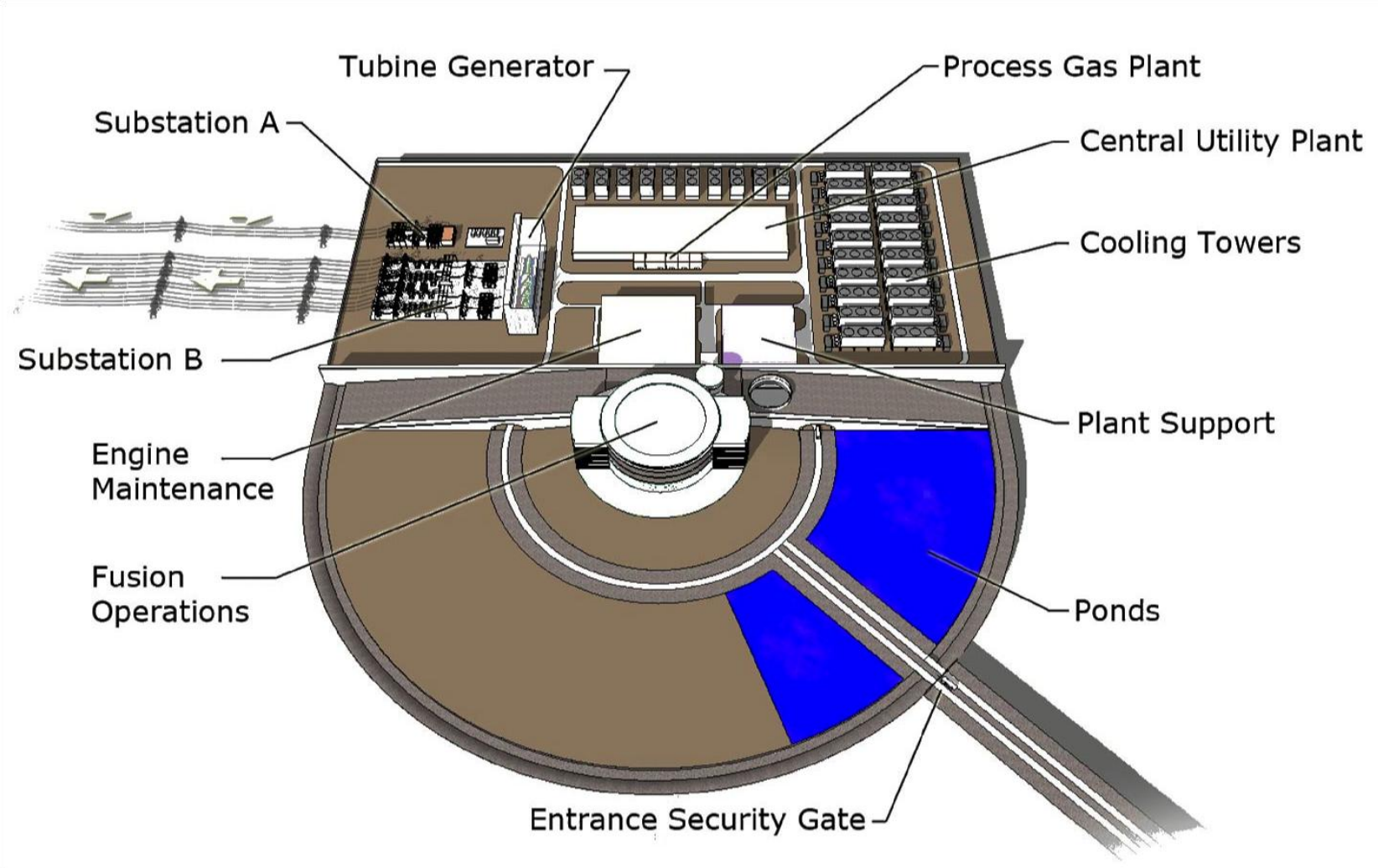
Performance-based licensing route (~10CFR70) looks likely

LIFE Power Plant

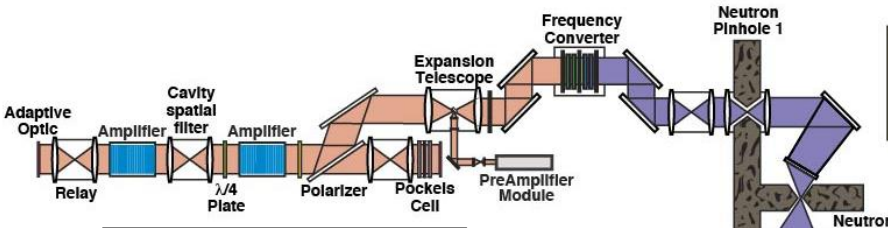


- Based directly on NIF performance
- Modular, factory built design for high plant availability
- Use of available materials and technologies
- Optimized for cost of electricity and market entry cost

The LIFE plant is designed to be compatible with existing baseload site location and scale



Principle of LIFE plant operation

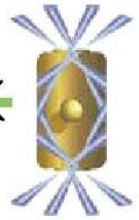


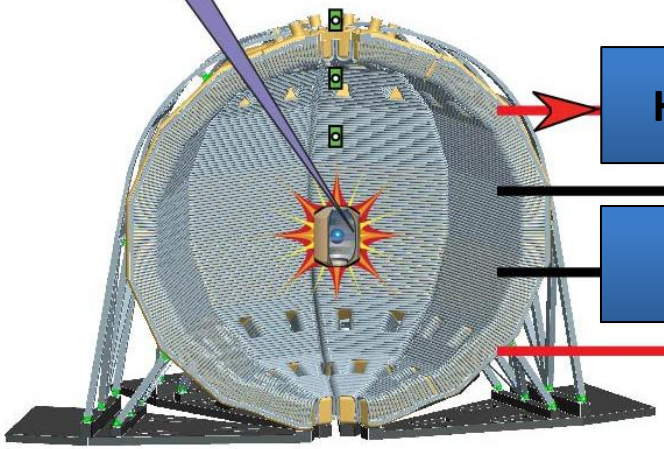
Laser driver

900 cycles / minute provides ~ 1 GWe output

Target Injection

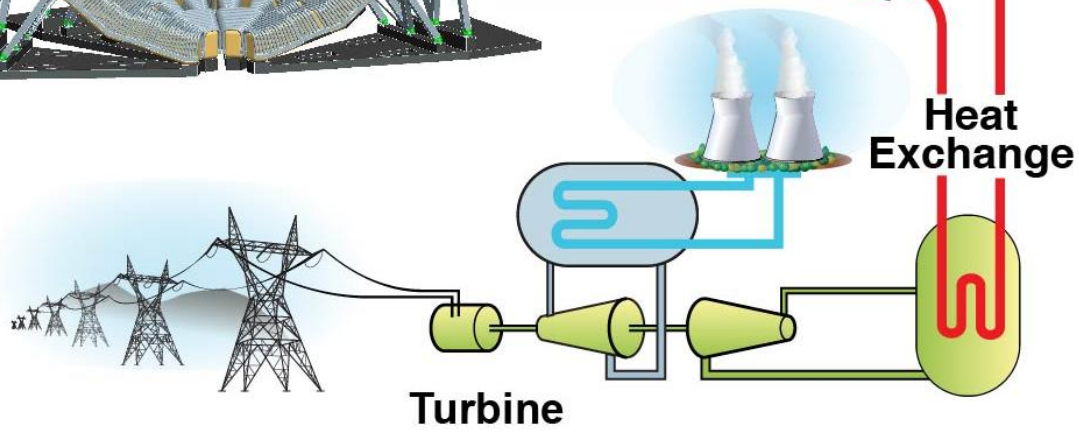
Target Fabrication





Heat transfer

Fuel cycle

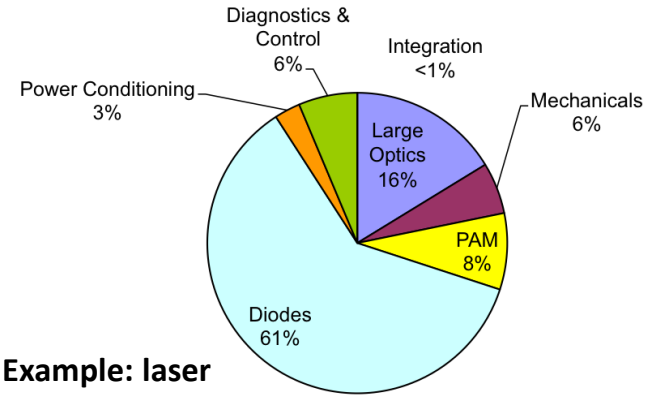


A detailed cost and economics model was iterated with the technology performance assessment

Economic factors

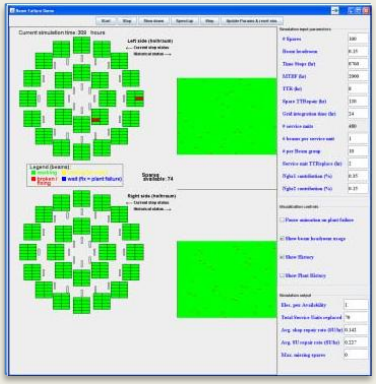
- Capital cost
- Availability
- Reliability
- Maintainability
- Fuel/consumable costs
- Licensing
- Supply chain
- Environmental cost
- Time to market

Capital cost areas

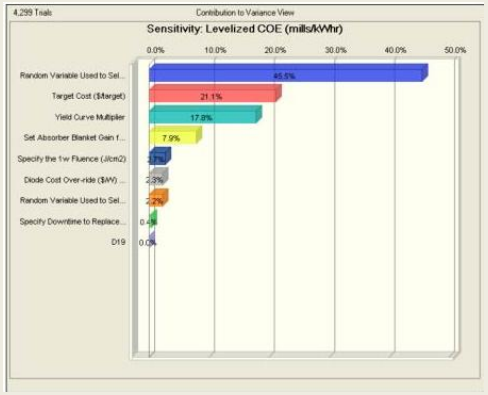


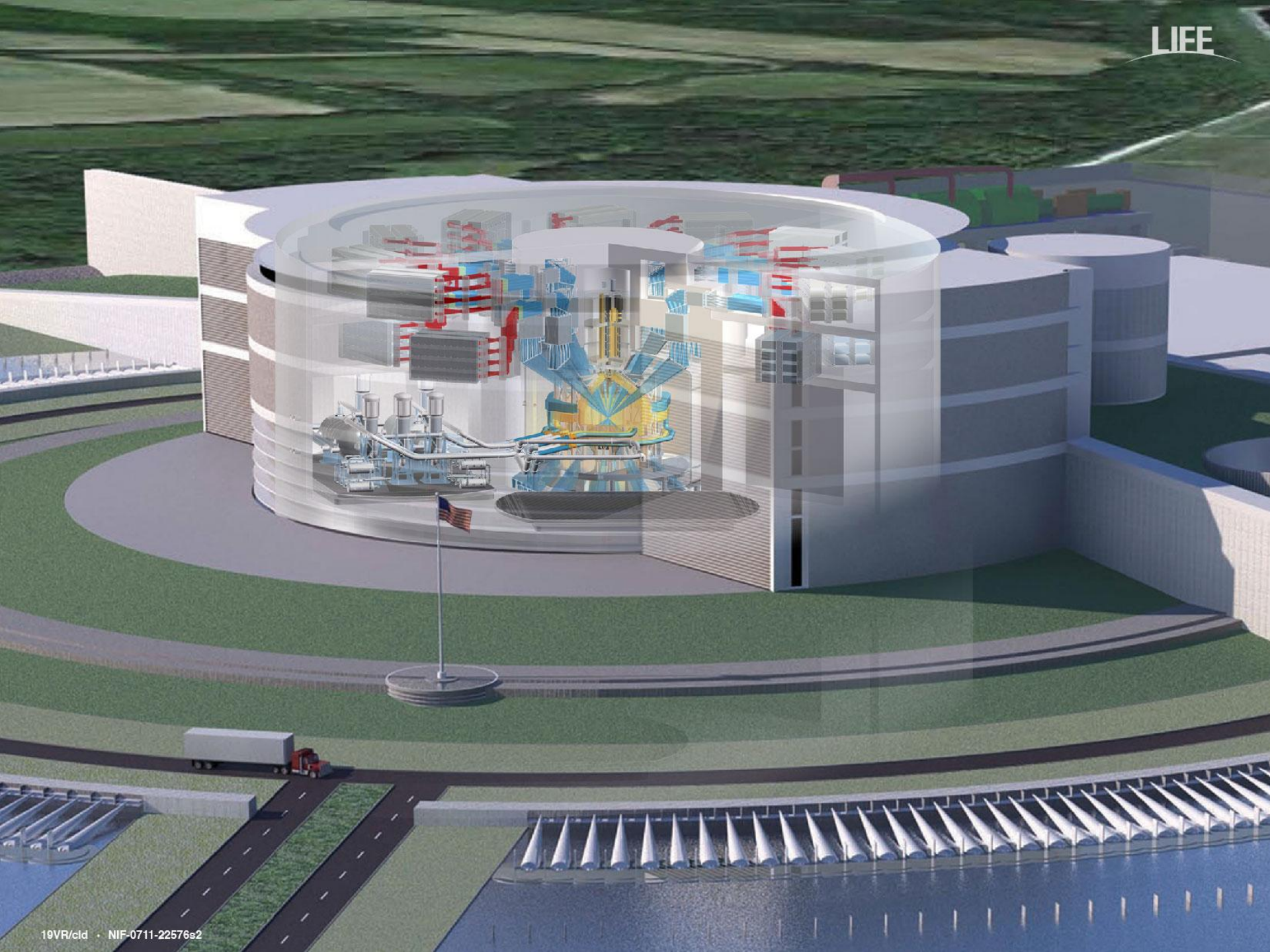
Example: laser

Monte Carlo availability



Technology investment impact




LIFE
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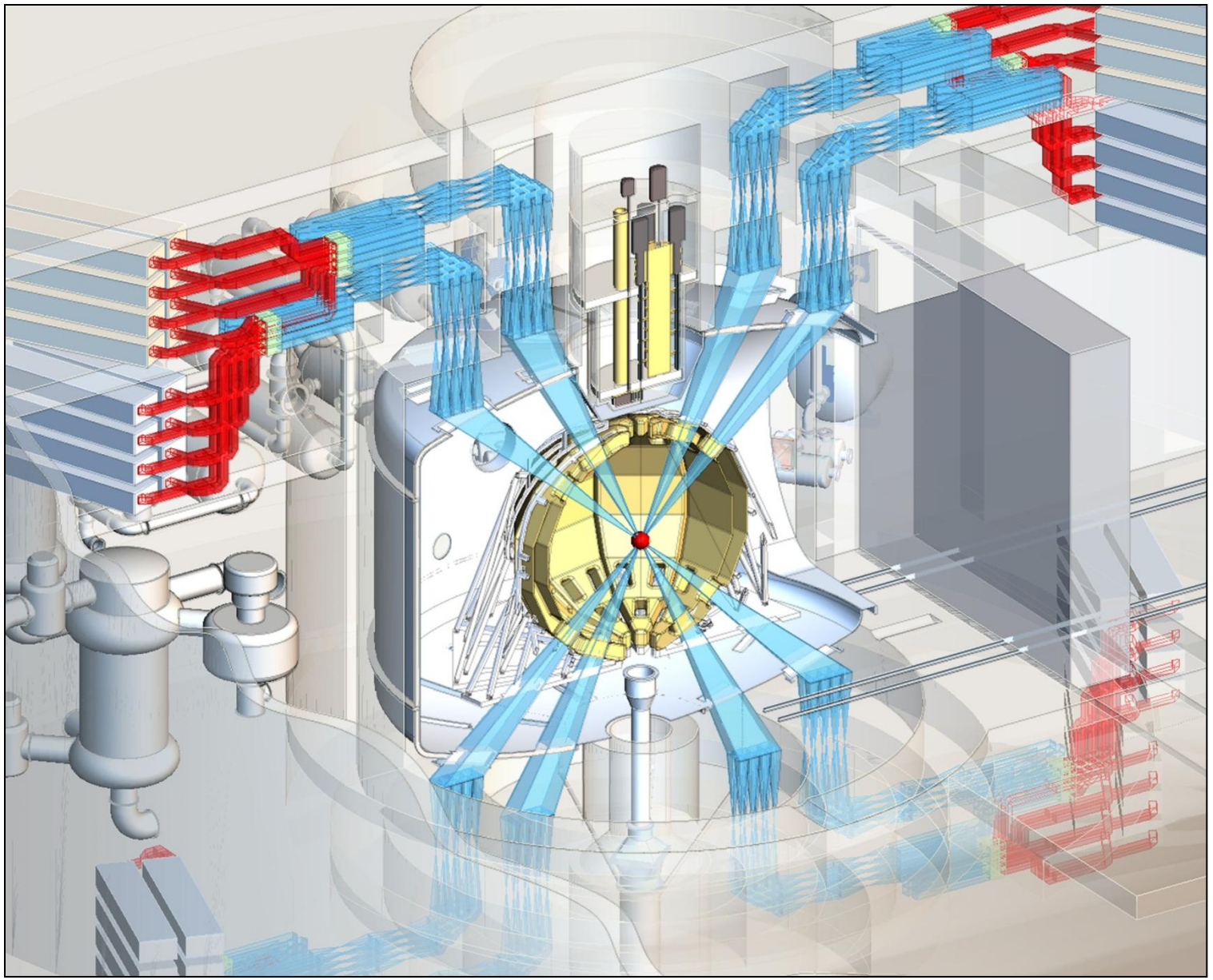


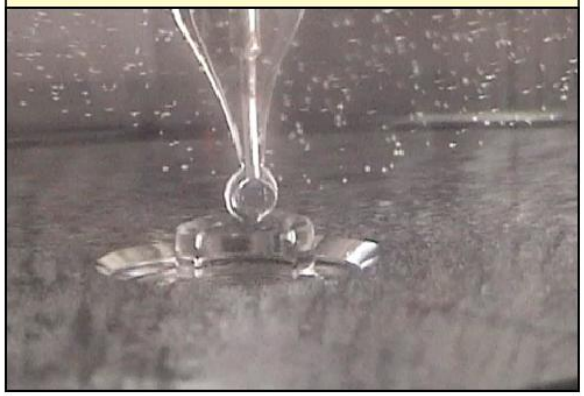
LIFE is designed to use commercially available technology and material

Semiconductor diode lasers

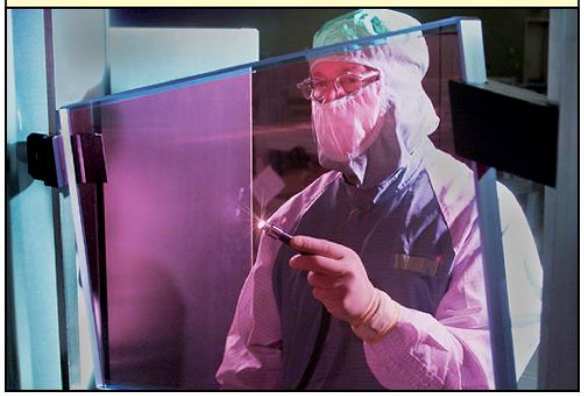
Conventional steel boiler

Steam turbine cycle

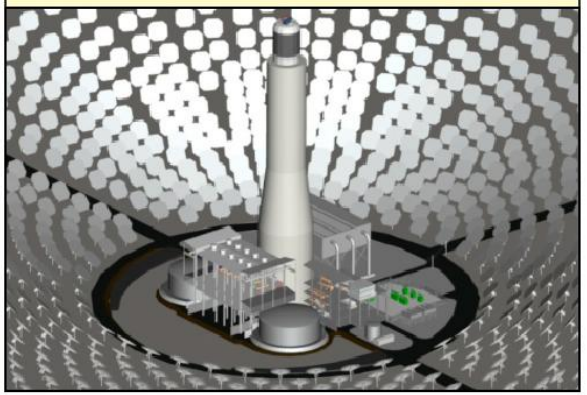
Mass manufacture of fuel



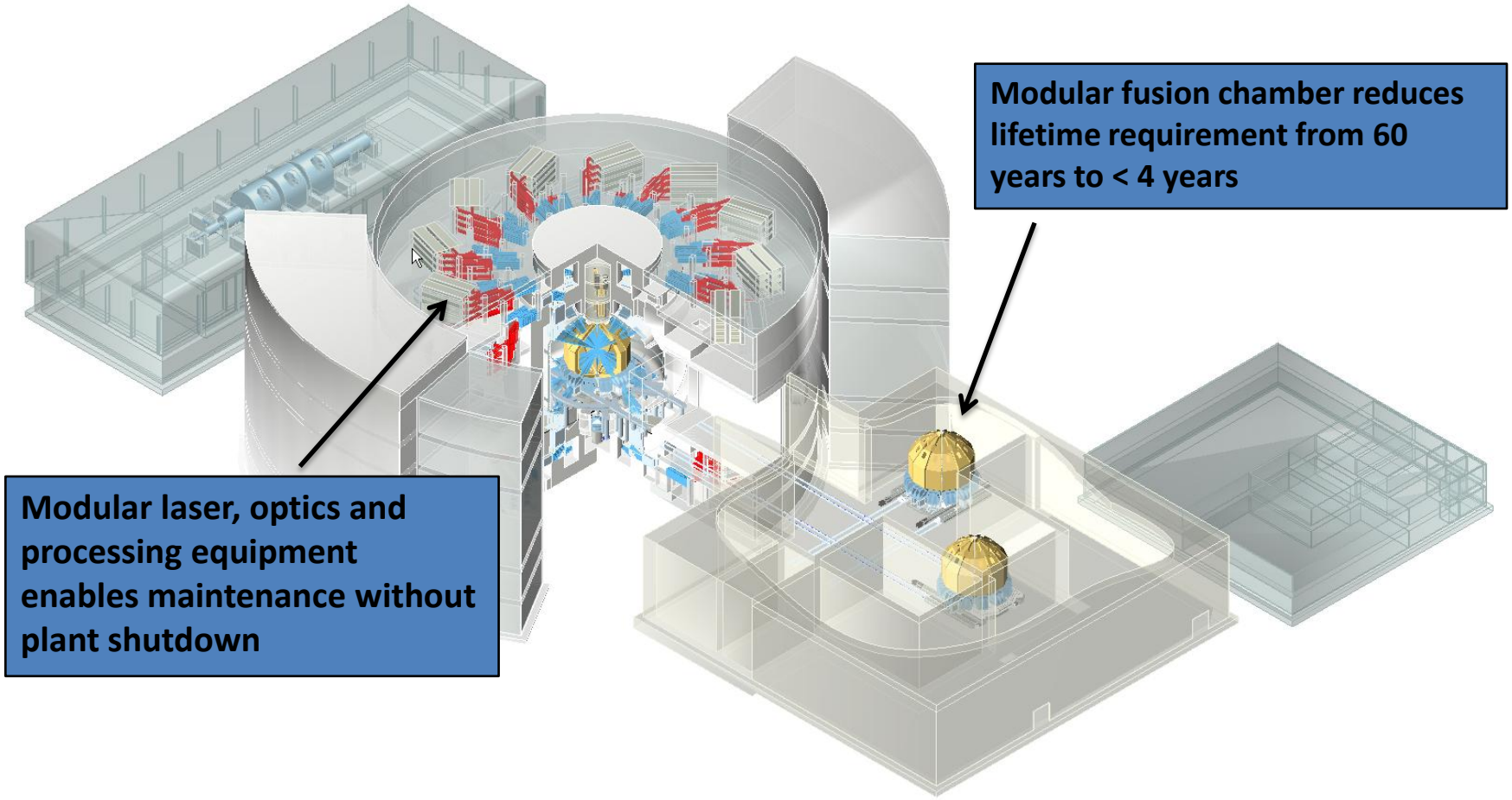
Optics production



Coolant systems



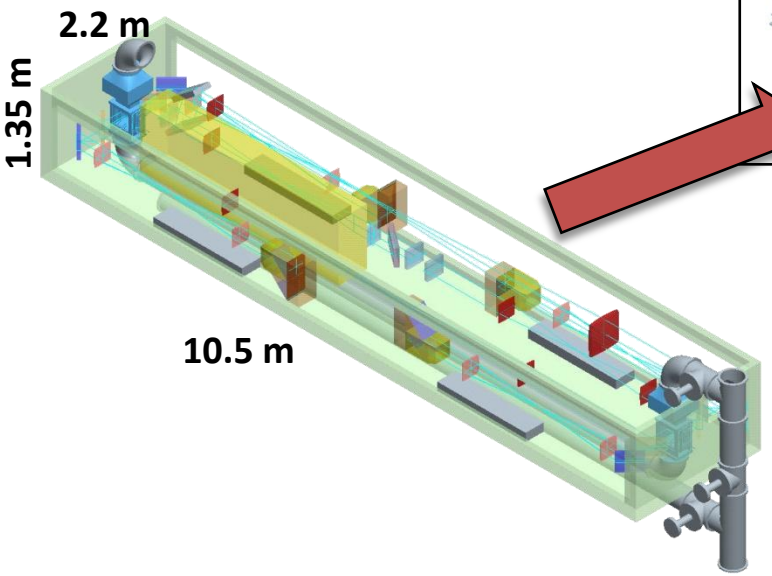
LIFE's modular architecture is what enables commercialization in a relevant timeframe

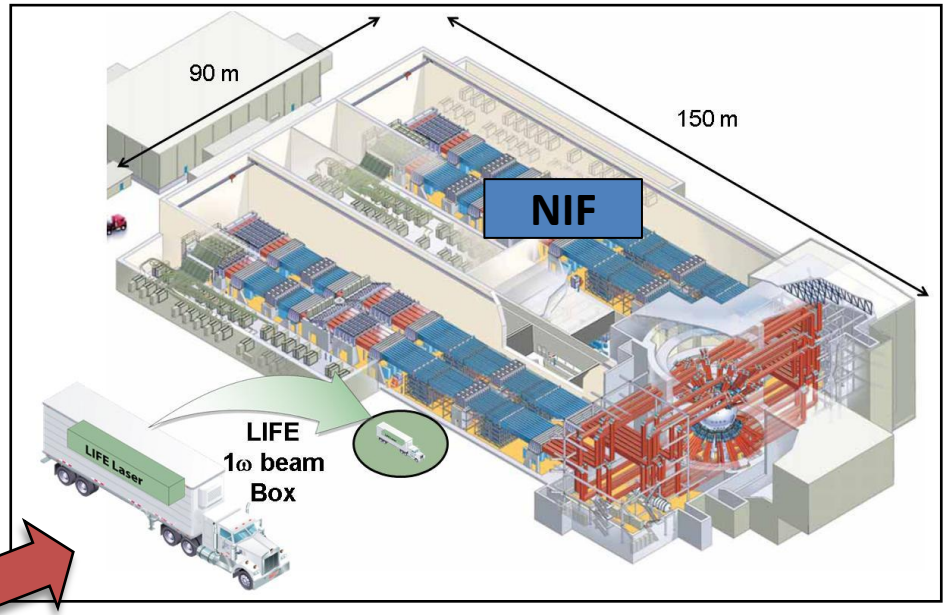


Fusion chamber can use conventional steel rather than wait for new radiation-resistant alloys to be developed

A LIFE beamline folds into a transportable box, enabling an efficient & cost-effective supply chain

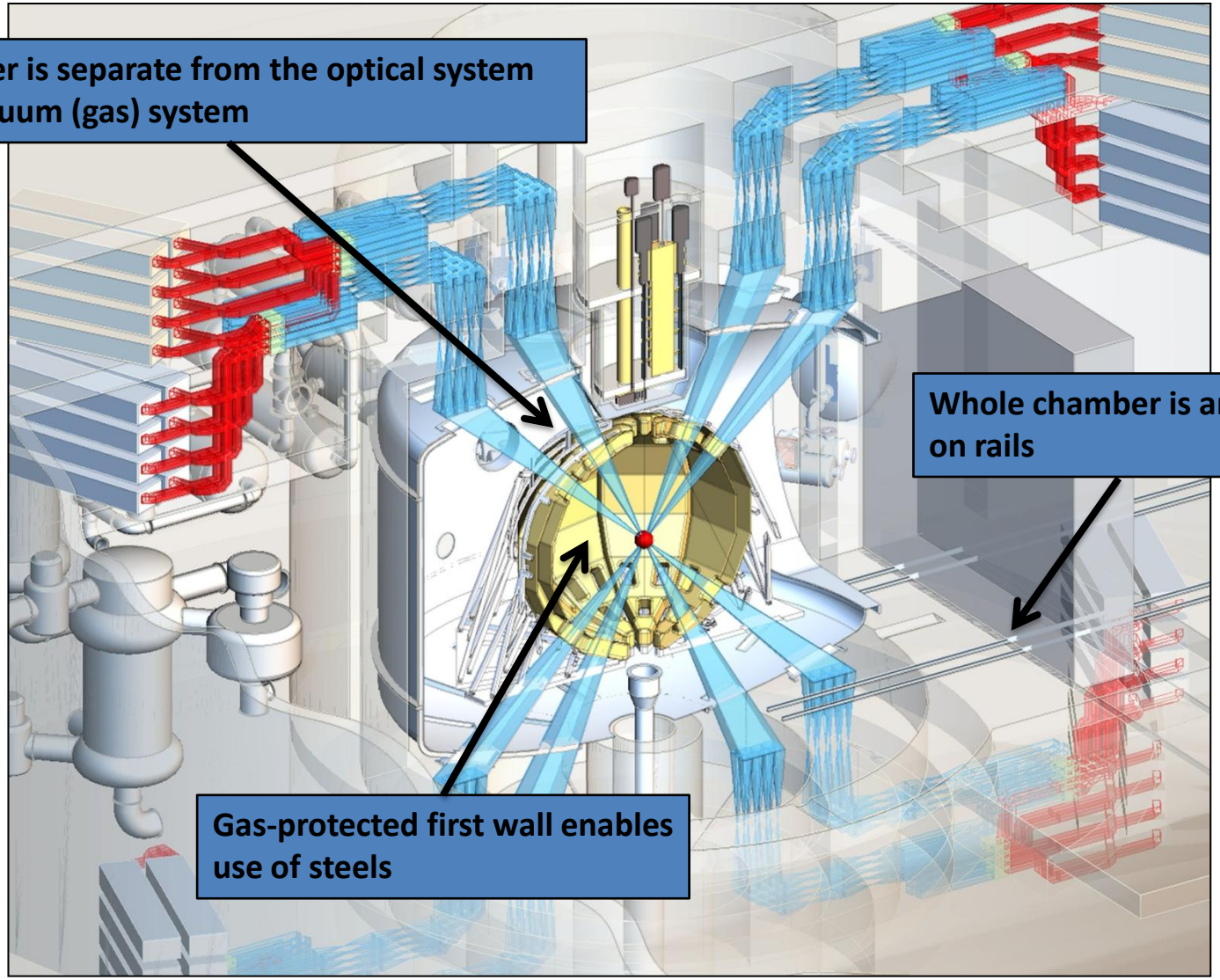
Ability to "hot swap" beamlines during plant operations.





- Offsite beamline factory
- Truck-shippable 1ω beamline
- Low-overhead installation
  - Kinematic placement
  - Few interfaces

… but LIFE will use a modular "boiler" assembly



Frequently Asked Questions of fusion

- **Evidence of Plasma Performance (will it work?)**
- **Power Plant availability and reliability**
- **Design simplicity and ease of construction, operations and maintenance**
- **Regulatory pathway, safety characteristics and waste stream**
- **Availability of materials and sub-system technologies**
- **Timeliness of delivery**

<u>Specifically for IFE:</u>

- **Mass Manufacture and Cost of Targets (Fuel)**
- **Fuel Injection accuracy**
- **Driver (laser) performance: efficiency, repetition rate**

Conclusions

- **LIFE addresses the primary criteria required for a baseload power plant**
  - guided by a group of utility executives and longstanding vendor partnerships
- **Uncertainties in plasma physics mandate the use of demonstrated fusion performance, and adoption of the tested driver geometry and characteristics**
  - i.e. Baseline on the NIF
- **LIFE allows substantial cost, time and risk reductions to be achieved by staged commissioning within a facility able to deliver GW output**
- **The LIFE solution leverages**
  - design, construction, operational and performance experience from NIF and a wide range of high average power laser systems
  - market availability for key technologies and materials
  - a single-step to commercial plant operation
  - international expertise and investment in LIFE-compatible technology

For More Information Visit

https://life.llnl.gov

https://lasers.llnl.gov

or

Simply Google “NIF”


LIFE